PCT

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :	(11) International Publication Number:	**WO 97/25657**
G05B 13/00	**A1**	
	(43) International Publication Date:	17 July 1997 (17.07.97)

(21) International Application Number: PCT/US96/20687

(22) International Filing Date: 19 December 1996 (19.12.96)

(30) Priority Data:
08/585,198 11 January 1996 (11.01.96) US

(71) Applicant: LEX COMPUTER AND MANAGEMENT COR-PORATION [US/US]; One Elm Street, Keene, NH 03431 (US).

(72) Inventors: SCHULER, Chester, L.; 57 Atkinson Lane, Sud-bury, MA 01776 (US). HABERMAN, Seth, M.; Apartment 6A, One West 85th Street, New York, NY 10024 (US).

(74) Agents: MICHAELIS, Brian et al.; Dike, Bronstein, Roberts & Cushman, 130 Water Street, Boston, MA 02109 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

---

(54) Title: METHOD AND APPARATUS FOR TACTILELY RESPONSIVE USER INTERFACE

(57) Abstract

A method and apparatus imple-menting a user interface device, such as a mouse or trackball, having electronically controllable tactile responsiveness which is flexibly programmable. The interface device includes at least two sets of wheels that move as the interface device is actu-ated. A servo motor (116) is attached to each of the at least two sets of wheels. A position encoder (118) is associated with each servo motor (116) and outputs posi-tion information to a controller (120).

METHOD AND APPARATUS FOR TACTILELY RESPONSIVE USER INTERFACE

1

2   ## FIELD OF THE INVENTION

3   The present invention relates to user interface devices and in

4   particular to devices providing tactile responsiveness and having

5   programmable   force-position   profiles   defining   tactile

6   responsiveness in manipulating a cursor on a screen display.

7   ## BACKGROUND OF THE INVENTION

8   In numerous contexts humans perform tasks by interacting with

9   machines via actuators having knobs, dials or linear actuators.

10 Such human interaction in many instances becomes conditioned upon

11 the responsiveness of the actuator. The human operator interacts

12 in accordance with tactile feedback perceived through contact with

13 the actuator knobs, dials or handles.

14   For example, in video or film editing using systems as

15 described in U.S. Patent Nos. 4,937,685 and 4,964,004 which are

1   incorporated herein by reference, an editor edits video image
2   information at a console having a plurality of "control wheels"
3   (i.e. large dials or knobs). The film or video editor controls
4   operation of a composition system from an operator's console, as
5   illustrated in Fig. 1, using two sets of controls, one for each
6   hand, to control the editing process. Each control set includes a
7   plurality of finger switches or pushbuttons 110 clustered proximate
8   to a large rotatable control wheel 112, facilitating tactile
9   operation with minimal hand movement. As the editor is focussing
10   on at least one video monitor, viewing frames of visual source
11   material during the editing function, it is generally the case that
12   the operator will acquire a feel for the various controls and
13   become acclimated to their functionality through tactile feedback
14   therefrom, rather than having to look at the control wheel(s) for
15   visual feedback. Accordingly, more efficient human interaction
16   with, and sensitivity to the composition system is achieved.

17   The control wheels 112 exhibit tactile responsiveness, such as
18   detents or clicks, as they are rotated. Typically, a full rotation
19   of the wheel 112 is correlated to a unit of time, such as one
20   second, of viewing the visual source material being edited. A
21   corresponding number of "frames" of visual source material will be
22   viewed during such a time period, depending on the medium or type
23   of source material being edited. It is most desirable that the
24   number of frames of source material be correlated to the tactile
25   responsiveness, i.e. number of clicks, of the wheel 112 during
26   rotation. For instance, film editing involves standardized source

- 2 -

1   material of which twenty-four (24) frames are provided per second.

2   Thus, it is most desirable that in a full rotation of the wheel 112

3   (presenting one second of source material), the wheel respond with

4   twenty-four (24) clicks, each click corresponding to one frame of

5   the visual source material.

6   While film editing involves source material having twenty-four

7   (24) frames per second, other video medium standards require

8   different frame rates. The frame rate, or number of frames per

9   second according to the National Television System Committee (NTSC)

10   is thirty (30) frames per second, a standard promulgated for

11   television video in the United States. Standards such as PAL and

12   SECAM provide for a standard frame rate of twenty-five (25) frames

13   per second in England and France respectively. New standards for

14   high definition television specify a frame rate of thirty (30) or

15   sixty (60) frames per second.

16   Differing frame rate standards relating to visual source

17   material and the nature of mechanical detents in actuators,

18   presents the problem that multiple actuators are required to

19   facilitate correlation between actuator tactile responsiveness and

20   the various visual source material standards. As illustrated in

21   Fig. 1a, actuators known in the art for providing tactile

22   responsiveness typically incorporate a mechanical detent mechanism.

23   A fixed number of clicks is provided by a spring loaded friction

24   mechanism 111 coacting with a sprocket 113 having a fixed number of

25   cogs or detents corresponding to the desired number of clicks per

26   revolution.   Therefore, an actuator having twenty-four fixed

- 3 -

1   detents is required and dedicated for a film editing context, a

2   thirty detent actuator is required for a NTSC video editing system,

3   a twenty five detent actuator is required in the PAL or CCAM video

4   editing context, etc. The plurality of actuators required limits

5   the flexibility of visual source material composition systems and

6   significantly increases the complexity, cost and hardware

7   requirements of a flexible system.

8   In addition to the lack of flexibility of use of fixed

9   mechanical detent actuators, such actuators disadvantageously

10   become worn and suffer tactile responsiveness degradation over

11   time. Other mechanically/spring loaded linear or rotary actuators

12   suffer similar deficiencies.

13   Likewise, other types of actuators or user interface devices

14   are known for permitting users to interact with electronic devices,

15   such as personal computers. Such user interface devices, like a

16   trackball or mouse as disclosed in U.S. Patent No. 4,868,549 ("the

17   '549 patent"), may include tactile responsiveness in the form of

18   resistance to movement of the device as the device is actuated and

19   the cursor moves across predetermined areas of the display screen.

20   In the '549 patent a mouse is disclosed which has an

21   electromagnetic means, in the form of an electromagnet in

22   conjunction with a magnetic surface or an electromagnetic brake,

23   which provides resistance to the movement of a "spherical ball

24   pickup". Feedback or tactile responsiveness is achieved in one

25   embodiment by controlling the degree of sliding friction between a

26   magnetic portion of the mouse and a magnetic pad surface on which

- 4 -

1   the mouse must be actuated.   Disadvantageously, the magnetic pad

2   surface is a requirement in such an embodiment, and the friction

3   forces between the pad and the mouse may be affected in ways that

4   may not be predictable and might be detrimental to the tactile

5   responsiveness.

6   In another embodiment in the '549 patent, an electromagnetic

7   brake is included and resistance is provided by the brake directly

8   to the spherical ball or tracking element.   The braking mechanism

9   is totally self-contained within the mouse eliminating the need for

10   a magnetic pad surface.   However, while the electromagnetic brake

11   provides a stopping mechanism, it cannot provide a continuous

12   torque to the tracking element, i.e. no torque is applied when the

13   tracking element is stopped.   Such a mechanism cannot be used to

14   change tactile responsiveness, e.g. to decrease resistance, as a

15   function of characteristics of a particular screen display.   The

16   resistance provided is only opposed to motion and cannot aid motion

17   by actively driving the ball to facilitate ease of motion in

18   certain display areas or to keep the cursor off of the boundary of

19   a restricted display area.

20

21   SUMMARY OF THE INVENTION

22   The present invention provides an actuator having

23   electronically controllable tactile responsiveness which is

24   flexibly programmable to facilitate provision in a single actuator

25   of torque-position characteristics, such as a selectable number of

26   detents per actuation through its full operative path.   In an

1   illustrative case of a rotary actuator the present invention

2   facilitates provision in a single actuator, of torque versus

3   angular position characteristics, such as a selectable number of

4   detents per revolution.

5   According to the invention, an actuator is in communication

6   with a servo motor having a position encoder which outputs position

7   information to a controller that has access to torque-position

8   relation information. The output of the controller is a digital

9   torque signal, in accordance with the torque-position relation

10   information, which is converted to an analog current signal applied

11   to the servo motor to generate torque in the servo motor. The

12   torque, presenting a tactile response to a human interacting with

13   the actuator, is sensed as a detent or a plurality of detents.

14   In further accord with the invention, the controller is a

15   microprocessor which receives position information, from the

16   encoder, through a counter as a position count. Torque-position

17   relation information is stored in microprocessor accessible

18   firmware as a table containing a series of particular torque values

19   corresponding to a series of particular position values. The

20   torque values, output as digital signals and converted by a digital

21   to analog converter, can be modified in accordance with a plurality

22   of stored torque versus position tables to facilitate flexible

23   programming of various torque profiles.

24   Features of the invention include the capacity to store and

25   modify torque profiles and to select one of a predetermined set of

26   torque profiles to provide an actuator with a desired tactile

1   responsiveness.   The torque profiles, stored for example, in

2   electrically erasable programmable read only memory can be changed

3   via a computer in communication with the microprocessor.   Upon

4   system power down and subsequent power up, a previously entered

5   torque profile can be present as a default profile.

6   In a further embodiment of the invention, a user interface

7   device, such as a trackball or mouse, is provided and implemented

8   with programmable tactile responsiveness.   In a mouse or trackball

9   embodiment, the device includes an interface mechanism comprised of

10 at least two sets of wheels that move as a spherical ball or

11 tracking element is actuated by a user.   The wheels are aligned on

12 mutually orthogonal axes and each of at least two sets of wheels

13 has a servo motor attached thereto and a position encoder

14 associated with each servo motor.   Position information from the

15 position encoder is received by a controller that has access to

16 tactile   force   information,   i.e.   torque-display   position

17 information.

18   The torque-display position information relates a position or

19 coordinate of a display entity or cursor on a display screen of an

20 electronic device to a force or torque applied to the user

21 interface device, effecting tactile responsiveness of the user

22 interface device as a function of the display screen on which the

23 display entity or cursor is manipulated.   The controller, having

24 received the display entity or cursor position information from the

25 position encoders, generates an output which is a digital signal in

26 accordance with the force-display position relation information.

- 7 -

1　　The force can be positive or negative, to assist or resist motion.

2　　In a disclosed embodiment, a digital torque signal output in

3　　accordance with torque-display position information is converted

4　　via a digital to analog converter, to an analog current signal

5　　which is applied to servo motors to generate torque in the servo

6　　motors. The torque generated in the servo motors is translated to

7　　the tracking element or ball of the user interface device and

8　　perceived by the user as tactile responsiveness that is a function

9　　of the position of the cursor on the screen display.

10　　　　Features of the invention include the capability to effect

11　　tactile screen boundaries, and "walls" and "troughs" which

12　　correspond to button bar functions or icon placement on a drag-down

13　　menu, by increasing and decreasing resistance to further

14　　manipulation of the interface device by the user, or by aiding

15　　motion of the device. "Bumps" and other textures can be

16　　implemented on the screen display and tactilely perceived as the

17　　cursor is moved. Cell boundaries can be defined by hard stops or

18　　"hills" which a cursor will roll off to limit access to screen

19　　areas or otherwise provide an indication of cursor position without

20　　requiring the user to look at the screen. Different tactile

21　　response profiles can be stored to correspond to different screen

22　　displays and user applications. Physically impaired people can

23　　interface to computer applications without the need for sight or

24　　fine motor skills.

25

DESCRIPTION OF THE DRAWING

These and other features and advantages of the present invention will become more apparent in view of the following detailed description in conjunction with the accompanying drawing, of which:

Fig. 1 is an illustration of an operator's console for editing visual source material in a composition system;

Fig. 1a is a partially broken-away view of an actuator according to the prior art having mechanical detents;

Fig. 2 is a block diagram of a system for providing programmable tactile feedback in an actuator;

Fig. 3 is a block diagram of a system for providing programmable tactile feedback in an actuator, wherein the controller comprises a counter, microprocessor and accessible firmware;

Fig. 3a is an illustrative diagram of an actuator and associated function keys for controlling multiple functions and providing multiple tactile responses in accordance with the selected function;

Fig. 4 is a block diagram of a system for providing programmable tactile feedback in an actuator, wherein the system further includes a tachometer sensing motor actuation to generate a corresponding actuation in an associated actuator;

Fig. 5A is a view of a prior art mechanical means for introducing resistance in an exercise machine;

Fig. 5B is a block diagram illustrating implementation of a

- 9 -

1　torque controller according to the invention implemented in an

2　exercise machine;

3　　　Fig. 6 is a block diagram of a joystick implementation of an

4　actuator with electronically controllable tactile responsiveness;

5　and

6　　　Fig. 7 is a perspective view, partially broken away, of a

7　trackball implementation of a user interface device according to

8　the invention;

9　　　Fig. 8A and 8B are front and side views, respectively, of a

10　wheel assembly implemented in the trackball of FIG. 1;

11　　　Fig. 9 is a plan view of the wheel assembly of Figs. 8A and 8B

12　attached to a motor and encoder assembly;

13　　　Fig. 10 is a diagrammatic representation of a pair of wheel

14　sets having motors and encoders associated therewith, and

15　contacting the tracking element;

16　　　Fig. 10A is a diagrammatic representation of a wheel set

17　disposed for a third axis (z-axis) responsiveness;

18　　　Fig. 11 is a diagrammatic representation of a user interface

19　device according to the invention configured to interface to a

20　personal computer;

21　　　Fig. 12 is a block diagram of a system according to the

22　invention; and

23　　　Figs. 13A-13D show a user interface screen and profiles for

24　tactile responsiveness implemented to effect characteristics of the

25　screen.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

1

2   Referring now to Fig. 2, an actuator, such as a rotary

3   actuator having a control knob 114 is attached via a shaft to a

4   servo motor 116.   In this illustrative embodiment wherein the

5   actuator is for use in a film/video editing context, the servo

6   motor is a PMI 12FVS motor.   In the present application, as

7   discussed in greater detail hereinafter, the servo motor is not

8   used as a motor per se, but rather as a torque controller. The

9   motor never runs at a significant amount of its rated revolutions

10 per minute, but operates normally in this application in a stalled

11 or semi-stalled state.   The preferred motor 116 has an installed

12 encoder 118.   The encoder 118 is a PMI M23, 300 segment modular

13 encoder having an index and providing 300 cycles per revolution,

14 which results in 1200 waveform edges from index to index.   Note

15 that in this illustrative embodiment it is important that the

16 encoder be selected to provide a number of edges which is divisible

17 by factors of two, three, five and eight.   Thus, position

18 information can be electronically divided to provide an integer

19 number of clicks in selectable modes of 24, 25 and 30 positions per

20 revolution (corresponding to the film/video editing standards of

21 24, 25 and 30 frames per second or revolution, as discussed

22 hereinbefore).

23   The position information received from the encoder 118 is

24 processed by a controller 120 so that it represents a positional

25 count.   The controller 120 accesses stored input data 122 in the

26 form of torque-position relation information which correlates a

- 11 -

1   received position count with a related torque value. As noted

2   hereinbefore, the position count, which is a function of encoder

3   output information, can be derived by electronically dividing

4   position information provided by the encoder waveform, as desired

5   into a selected number of positions or position values. The input

6   data 122 accessed by the controller 120 will have stored torque

7   values associated with the selected position values as provided in

8   accordance with the desired torque profile. The controller 120

9   outputs the torque value as a digital signal which is converted by

10   a latchable digital to analog converter 124 to an analog voltage.

11   As a voltage applied to the motor would result in a proportional

12   motor speed, the analog voltage is related to motor torque by

13   generating a proportional motor current using a power amplifier 126

14   in conjunction with a motor power supply 128. The torque related

15   current is applied to the motor 116 to present the desired torque

16   which imparts the desired tactile responsiveness to the control

17   knob 114.

18   In an embodiment illustrated in Fig. 3, the controller 120

19   comprises a counter 130 which receives the servo motor position

20   information from the encoder 118. A microprocessor 132, such as a

21   Motorola 6809, receives a position count from the counter 130

22   providing an indication of servo motor position relative to the

23   index. The count provided by the counter will increment or

24   decrement depending on the direction of the change of position of

25   the servo motor. The microprocessor accesses electrically erasable

26   programmable read only memory 134 (EEPROM) which is programmed with

1   one or more tables of torque-position relation information. Each

2   table defines a particular torque profile specifying a torque value

3   corresponding to a particular position count (i.e. knob/servo motor

4   position).

5   A main application CPU 136 runs an application which requires

6   and defines particular torque profiles for the actuator 114. The

7   main application CPU may run an application which defines the

8   functionality of a control wheel and related function buttons as

9   illustrated in Fig. 3a. In this illustrative embodiment the

10   control wheel has an outer dial 140 which according to the

11   application performs a first function having a fixed number of

12   positions, such as selecting one of a plurality of switch settings.

13   The application can assign a second function to the same outer

14   dial 140 and provide a profile assigning an alternative

15   responsiveness to the outer dial actuator, such as assigning a

16   lever control function having electronically defined stop

17   positions, when a shift key 142 is depressed. An inner control

18   knob 144 similarly can be assigned a first function and

19   corresponding torque profile (such as a free running non-detent

20   scan function), by the application running on the main application

21   CPU, and a second (or other) function and corresponding torque

22   profile (such as a 30 detent per rotation edit mode, as discussed

23   hereinbefore), which is invoked such as by depressing an alt

24   key 146.

25   The main application CPU 136, upon application initialization,

26   down loads the desired torque profiles to the microprocessor

- 13 -

1   accessible EEPROM, via an RS-232 serial, or other communication
2   port. The desired torque profiles reside in EEPROM and are
3   selectable via the microprocessor for providing the desired torque
4   at the appropriate actuator position(s) in accordance with the
5   requirements of the main application. A desired torque profile can
6   be selected by a user operating the control knob 144 or outer
7   dial 140 actuators, alone or with other control functions such as
8   the alt or shift keys, to be responsive in accordance with the
9   first or second function. A change in actuator function, and a
10   corresponding change in actuator responsiveness (i.e. torque
11   profile) can be effected via selected key strokes, such as a shift
12   key or function key implementation discussed.

13   The EEPROM resident tables will not change until a new set of
14   profiles is programmed, i.e down loaded, into the microprocessor
15   accessible memory. Thus, when the system is powered down and
16   subsequently powered up, the previously selected torque profile is
17   resident and available as a default mode for the respective
18   actuators.

19   As illustrated in Fig. 4, the selectable torque profiles and
20   tactile responsiveness of the actuator according to the invention
21   can be implemented so that a second actuator 150 is responsive to
22   a first actuator 114', operating substantially as discussed
23   hereinbefore. In certain operations it is desirable to have two
24   actuators working in conjunction according to a common torque
25   profile. In such a case, the servo motor of one actuator can be
26   used to actually drive a second motor, in addition to its function

- 14 -

1   as a torque controller.

2   For instance, it is desirable when editing film, to turn the

3   first actuator 114' to add one or more frames to one end of the

4   composition material while removing one or the same number of

5   frames from an opposite end of the composition material controlled

6   by the second actuator 150. In such a case, rather than trying to

7   turn the respective control knobs exactly the same amount, it would

8   be best to have the second actuator 150 respond according to the

9   first actuator 114' and its associated torque profile.

10   As the first actuator 114' is manually rotated N clicks as

11   sensed according to its torque profile implemented as discussed

12   hereinbefore with respect to Fig. 3, the encoder 118' and a

13   tachometer 152 associated with the first actuator 114' indicate the

14   direction and speed, respectively, of the first actuator 114' to

15   the microprocessor 132'. The direction and position of the first

16   actuator 114' is received from the encoder 118' through the

17   counter 130'. The rate of change of position, i.e. velocity, is

18   indicated by the tachometer 152 as an analog signal, which must be

19   converted by an analog to digital converter 154 for processing

20   digitally by the microprocessor 132'. The microprocessor 132', in

21   accordance with the count received from the first actuator 114' and

22   a velocity profile, generates a digital signal which is delivered

23   to the second actuator digital to analog converter 156 and

24   converted to an analog signal, increasing power to a second

25   actuator servo motor 158. The power increase to the second

26   actuator servo motor 158 results in an actuation of the second

1 motor in a direction according to the direction sensed, and

2 according to an operation directed by the microprocessor. The

3 microprocessor monitors a second actuator encoder 160 to read a

4 complementary count from the second actuator 150 being driven, and

5 monitors a second actuator tachometer 160 to sense a velocity

6 comparable to that of the first actuator being manually actuated.

7 When the comparisons indicate that the second actuator is actuated

8 in accordance with the manual actuation of the first actuator, the

9 operation is complete.

10 While the implementation of a driven actuator describes a

11 tachometer for determining velocity of the actuators, it will be

12 appreciated that velocity can be derived by the microprocessor

13 using a mathematical operation which takes the first derivative of

14 the rate of change of position information, eliminating the need

15 for a tachometer. Further, although a motor power supply is

16 indicated in Fig. 4 for each servo motor, it can be appreciated

17 that a single power supply can be used for both motors.

18 Although the invention is described herein in the context of

19 an actuator in a film/video editing context, one of ordinary skill

20 in the art will appreciate that selectably programmable tactile

21 responsiveness according to the invention can be provided in many

22 contexts in which mode selection of tactile responsiveness is

23 desirable.

24 While the actuator having electronically controllable tactile

25 responsiveness is described herein as providing a selectable number

26 of detents or clicks per rotation of a control wheel, it can be

- 16 -

1   appreciated that other torque profiles, such as progressively

2   increasing torque in one direction or another or increasing torque

3   to a point of a pseudo hard stop, can be achieved according to the

4   invention by introducing a torque profile which results in an

5   appropriate current applied to the servo motor.

6   Further, although programmable tactile responsiveness is

7   described in the context of a rotary actuator application, it will

8   be appreciated that selectable tactile responsiveness can be

9   implemented according to the invention in other applications and

10   actuator contexts, such as in linear actuator contexts.

11   Referring now to Fig. 5A and 5B, it will be appreciated by

12   those of ordinary skill in the art in view of the foregoing, that

13   the electronically controllable tactile responsiveness according to

14   the invention can be implemented in actuators other than knob type

15   actuators and in contexts other than video or film editing

16   contexts. Various exercise machines have mechanisms for providing

17   resistance, such as the mechanism illustrated in Fig. 5A. The

18   linear motion of an exerciser pulling alternately on the handles

19   300, 302 of Fig. 5B is translated and imparts a rotary motion to a

20   take-up spool 304 (Fig. 5A and 5B). In known exercise machines,

21   resistance is introduced at the take-up spool by tightening a

22   mechanical/spring mechanism 306 (Fig. 5A) which increases the work

23   required to impart linear motion to the handles 300, 302. The

24   system according to the invention and described hereinbefore can be

25   implemented in such a context by introducing a bidirectional servo-

26   motor 308 (Fig. 5B) which is adapted to receive bidirectional

- 17 -

1 torque versus position information in the form of current profiles

2 resulting in resistance similar to that introduced by the

3 mechanical means of 306 of Fig. 5A. The current provided by the

4 torque controller 310 is a function of torque adjust profiles 312

5 which are selectable/programmable and stored in a manner as

6 discussed hereinbefore.

7   Similarly, referring now to Fig. 6, programmable tactile

8 responsiveness can be implemented in an actuator such as a joystick

9 actuator 400. In such a context, torque profiles are stored in

10 tables within a torque controller 402 in the form of at least two

11 tables for containing profiles to control motors in at least two

12 axes. A first servo motor 403 is attached to a sphere 404 to which

13 a joystick 406 is fixed. The first motor 403 is fixed to the

14 sphere 404 to which the joystick is fixed and controls the tactile

15 responsiveness of the joystick 406 as it is linearly actuated in

16 directions indicated by the arrow A-B. The linear motion of the

17 joystick in the direction A-B is translated into a rotary motion by

18 a shaft 408 forming an axis about which the joystick 406 rotates in

19 a limited manner. The torque controller 402 contains at least one

20 profile table that determines the current provided to the first

21 servo motor 403 and ultimately determines the particular

22 responsiveness of joystick 406 as it is actuated in directions A-B.

23   A second servo motor 410 is mounted to a fixed frame or

24 surface 412 and controls responsiveness of the joystick 406 as it

25 is actuated in the direction indicated by arrow C-D. An assembly

26 comprised of the sphere 404, joystick 406 and first motor 403 is

- 18 -

1   capable of limited rotation about an axis formed by a shaft 414

2   which is connected at a first end to the second motor 410 and at a

3   second end to a bearing 416. As the joystick 406 is actuated in

4   the direction C-D, the sphere 404, and first motor 403 to which the

5   joystick 406 is attached is actuated having a responsiveness as

6   determined by at least a second profile table stored in the torque

7   controller 402.

8   Although the illustrative embodiments of the exercise

9   implementation and joystick implementation describe controlled

10   tactile responsiveness in a single axis and double axis context

11   respectively, it will be appreciated by those of ordinary skill in

12   the art that tactile responsiveness can be implemented in a

13   plurality of axes greater than 2.

14   Furthermore, it will be appreciated by those of ordinary skill

15   in the art that various mechanisms, such as the spool of the

16   exerciser implementation, are useful for translating torque into

17   linear force and/or linear force into rotational torque, and that

18   the tables discussed hereinbefore while containing torque versus

19   position profiles can be programmed to comprise force versus linear

20   position profiles.

21   Referring now to Figs. 7-9, a user interface device can be

22   implemented according to the invention, to include tactile

23   responsiveness as a function of the position of a display entity,

24   e.g. cursor, on a screen display. In this illustrative embodiment

25   a trackball 500 is implemented including a plurality of sets of

26   drive wheels 502 which contact a tracking member or ball 504. As

1 will be understood by those of ordinary skill in the art,

2 manipulation of the tracking member or ball 504 effects

3 manipulation or movement of a cursor on a screen display (not shown

4 in Figs. 7-9). The details of construction and manufacture of a

5 trackball and/or mouse implementation will be understood by those

6 of ordinary skill in the art, and therefore will not be presented

7 here other than to present significant components and their

8 interrelationships.

9 In this illustrative embodiment, the tracking member or ball

10 is interconnected in the user interface device by an

11 interconnection mechanism comprised of sets of drive wheels. Each

12 of the sets of drive wheels 502, best illustrated in Figs. 8A and

13 8B, is comprised of a hub 506 about which at least one frame

14 structure 508 is configured. The frame(s) 508 have a plurality of

15 frame portions each extending longitudinally through a respective

16 one of a plurality of barrel-shaped gripping members 510.

17 Preferably, the outside radius of a large portion of the gripping

18 members 510 is equal to the outside radius of the drive wheels 502.

19 Two drive wheels are used, offset slightly, to make the contact

20 with the ball 504 smooth so as to avoid a "bumpy" feeling as the

21 ball 504 is actuated and in turn actuates the wheels 502. The

22 gripping members are each rotatable around the frame portion that

23 extends through and supports it. The gripping members 510 are made

24 of a polymeric material suitable for establishing gripping contact

25 with the ball 504. In this illustrative embodiment, as illustrated

26 in Fig. 8A, two frames 508 are configured about the hub 506. The

- 20 -

1   gripping members 510 are offset or staggered in order to compensate

2   for gaps between gripping members on a respective frame, to

3   maintain a gripping member in contact with the ball 504 at all

4   times.

5   Each pair of frames 508 attached to a common hub 506 and with

6   associated gripping members 510, constitutes a wheel set that is

7   attachable, as illustrated in Fig. 9, to a servo motor 512 and

8   encoder 514 to form a drive/position assembly 516. In this

9   illustrative embodiment the drive/position assembly servo motor is

10   used actively as a motor. The servo motor may be a Pittman Model

11   No. 8322 (manufactured by Pittman, Harleysville, PA), which

12   optionally comes with an integrated optical encoder which fulfills

13   the encoder requirement. At least one drive/position assembly 516

14   is configured to apply torque and sense position along a respective

15   one of mutually orthogonally disposed axes, e.g. an x-axis

16   corresponding to cursor movement across a display screen, a y-axis

17   orthogonally disposed with respect to the x-axis and corresponding

18   to cursor movement up and down on a screen, and a z-axis

19   orthogonally disposed with respect to the x and y axes and

20   corresponding to cursor movement in and out of a screen in a three

21   dimensional configuration. In some instances, as described

22   hereinafter, a wheel set is attached to a motor without an encoder,

23   or just a bearing 518 to implement a complementary slave assembly

24   520 when it may not be desirable to include additional servo motors

25   and/or encoders. The referenced servo motor, without an encoder,

26   may be employed passively as a bearing.

1   To implement a two dimensional user interface device, e.g.

2   trackball or mouse, the tracking element or ball 504 is configured

3   to have at least two drive/position assemblies 516 positioned with

4   the gripping members 510 in contact with the ball. As illustrated

5   in Fig. 10, a first drive/position assembly 516 is positioned with

6   the gripping members of its wheel set in contact with the ball, and

7   includes a servo motor and encoder. A first complementary slave

8   assembly 520 is positioned opposed to the first drive/position

9   assembly 516 and has gripping members of its wheel set engaging the

10   side of the ball 504 opposite the first drive/position assembly

11   516.

12   A second drive/position assembly 516' is positioned on an axis

13   orthogonal with respect to the first drive/position assembly 516

14   and has a servo motor and encoder attached thereto. A second

15   complementary slave assembly 520' is positioned opposed to the

16   second drive/position assembly 516' and has gripping members of its

17   wheel set engaging the side of the ball 504 opposite the second

18   drive/position assembly 516'. In the illustrative two dimensional

19   implementation, the complementary slave assemblies include motors

20   that are slaved to the motors of the drive/position assemblies.

21   Such slaved motors produce a complementary torque to assist the

22   drive/position assemblies in applying a more balanced torque to the

23   ball. It will be appreciated that a less expensive device can be

24   implemented according to the invention by merely having the wheel

25   sets opposed to the drive/position assemblies configured with a

26   bearing to passively engage the ball.

- 22 -

1   As illustrated in Fig. 10A, in implementing a three

2 dimensional user interface device according to the invention, a

3 drive/position assembly 516'' is positioned along a circumference

4 of the ball 504 such that the orientation of the wheel set is

5 orthogonally disposed with respect to the orientation of the wheel

6 sets of the x and y axis assemblies (in Fig. 10A for simplicity

7 only one wheel set 516 is shown exemplifying the orientation of the

8 x and y axis assemblies). The z-axis drive/position assembly 516''

9 is preferably configured with a complementary slave assembly 520''

10 disposed along an axis that is perpendicular to an axis along which

11 the drive/position assembly 516'' is disposed. Although the

12 functionality of a two dimensional implementation is described

13 hereinafter for ease of explanation, it will be appreciated that a

14 z-axis drive/position assembly and complementary slave assembly can

15 readily be implemented in a user interface device that is

16 responsive in three dimensions.

17   Referring now to Figs. 11 and 12, the drive/position

18 assemblies 516 and complementary slave assemblies 520 are

19 configured with the ball 504 (not shown in Figs. 11 and 12), as a

20 user interface device 500 in a system that includes an electronic

21 device or computer system 528 with a screen 530 on which a cursor

22 is positioned on a screen display or graphical user interface, as

23 known in the art. The computer to which the user interface device

24 500 is connected has an operating system and is capable of running

25 various application programs which result in various screen

26 displays on which the cursor is manipulated using the user

1 interface device 500.

2   The user interface device 500 includes at least a first and

3 second drive/position assembly 516, 516' each with a servo motor

4 534 and encoder 536 and associated first and second complementary

5 slave assemblies 520, 520' for respectively sensing y-axis and x-

6 axis ball movement to be translated into a cursor position on the

7 display. In this illustrative embodiment, each of the servo motors

8 in the drive/position assemblies is connected in series with its

9 respective complementary slave assembly motor which results in the

10 motor pairs seeing the same current. In the present application

11 each servo motor 534 is not used as a motor per se, but rather as

12 a torque controller. The motor never runs at a significant amount

13 of its rated revolutions per minute, but operates normally in this

14 application in a stalled or semi-stalled state. The preferred

15 motor, as discussed hereinabove, has an installed encoder 536. The

16 encoder 536 is matched to the motor and the motor application as

17 appreciated by one of ordinary skill in the art.

18   The computer or electronic device 528, as known in the art,

19 is configured to accept an interface board 532 which includes the

20 mechanisms required to electronically interface the user interface

21 device 500 to the computer system 528 and display 530. The

22 interface board 532 is typically configured to reside in an I/O

23 slot of the computer 528 and includes a microprocessor 538 which

24 communicates with the computer 528 via a serial communication

25 channel 540. In the embodiment illustrated in Fig. 11, the

26 interface board 532 comprises a counter 542 associated with each

- 24 -

1 encoder 536. Each counter 542 receives servo motor position

2 information from the encoder 118. The microprocessor 538, such as

3 a Motorola 6809, receives a position count from each counter 542

4 providing an indication of position of each servo motor relative to

5 an index. The count provided by the counter will be incremented or

6 decremented depending on the direction of the change of position of

7 the servo motor relative to the index, which is indicative of a

8 change in position of the ball and the cursor on the screen

9 display.

10 The microprocessor 538 accesses torque profile information

11 from a storage mechanism as a function of the coordinate position

12 indicated via the encoders, i.e. x-axis position and y-axis

13 position. The storage mechanism can be internal to the

14 microprocessor and/or external in the form of additional torque

15 profile storage 545 (such as EEPROM, ROM, disk, CDROM etc). The

16 torque profile information provides an indication of a torque or

17 force to be applied by/to the motor. The torque is a function of

18 the position of the cursor on the screen and a function of the

19 particular screen display on which the cursor is being manipulated.

20 As in the embodiments described hereinbefore, the torque

21 value, in this case a value for each motor or axis, is output from

22 the storage mechanism as a digital signal which is converted by a

23 latchable digital to analog converter (D/A) 544 to an analog

24 voltage. As a voltage applied to the motor would result in a

25 proportional motor speed, the analog voltage is related to motor

26 torque by generating a proportional motor current using a power

- 25 -

1 driver or amplifier 546 (for each motor). The torque related

2 current is applied to the motor(s) 516, 516', 520, 520', to present

3 the desired torque which imparts the desired tactile responsiveness

4 to the ball 504.

5 The computer 528 runs an application, or several applications,

6 which requires and defines particular torque profiles for the user

7 interface device 500. Each screen display of an application

8 running on the computer has torque profile information associated

9 with that particular screen display to effect a corresponding

10 particular tactile responsiveness for that screen display. The

11 torque profile information which is being processed is stored in

12 the microprocessor. Additional torque profile information which is

13 not immediately required for a running screen display can be stored

14 in external memory associated with the microprocessor 545. The

15 torque profile information represents a spatial array that

16 indicates the relationship of motor currents or torques as a

17 function of position parameters for each axis present in the

18 embodiment. In this illustrative embodiment the array must contain

19 torque information for x and y axis motor pairs as a function of

20 the x and y coordinate position of the cursor on the particular

21 screen display(s).

22 Preferably, a large volume of torque profile information

23 defining the tactile responsiveness of numerous screen displays of

24 an application software package or an operating system is stored in

25 a database associated with a particular application or applications

26 that run on the computer. As illustrated in Fig. 12, the computer

- 26 -

1   typically runs an operating system or main application 550 which is
2   stored on some external storage medium such as a disk or CD ROM and
3   paged or transferred to the computer's main memory as the
4   application code is running.

5   A database of torque profiles 552, as part of an application
6   running under the operating system or with the application 550,
7   defines the tactile responsiveness of the user interface device
8   based on the screen displays of the application(s). The torque
9   profile information 552 is accessible to the application(s) or
10   operating system(s) via the application's application program
11   interface (API), as known in the art. The torque profiles relate
12   the tactile responsiveness of the user interface device 500 to the
13   graphical user interface(s) or screen display(s) of the application
14   550, as respective torque profiles are downloaded or made available
15   to the microprocessor 538 on the interface board 532 to generate
16   the appropriate digital signals in response to the position
17   information received from the encoders, as discussed hereinbefore.

18   A user interface device driver 554 facilitates communication
19   between the microprocessor 538 on the interface board 532 for the
20   user interface device 500, and the host computer 528. The
21   microprocessor computes coordinates for a change of cursor position
22   by processing the information received from the encoders and
23   information known about the original position of the cursor as
24   provided by the host computer over the serial channel 540. The
25   driver communicates the information related to cursor position to
26   and from the host computer which effects actual positioning of the

- 27 -

1   cursor. In the present embodiment, the driver 554 is generic to
2   the user interface device 500 and is modified slightly from a mouse
3   or trackball I/O device driver as known in the art, in that the
4   driver 554, through an interface to the torque profile information
5   552 and application software 550 coordinates the downloading of
6   appropriate torque profile information to the microprocessor based
7   on indications from the application 550 as to the appropriate
8   torque profile.

9   Based on the application being run on the host 528, the driver
10   554 running on the host communicates relevant torque profile
11   information to the microprocessor 538.   The driver also
12   communicates information to the microprocessor regarding the
13   present position of the cursor on the display screen of the host
14   528. In response to the coordinate information of the cursor on
15   the display screen, the microprocessor 538 generates digital
16   information corresponding to the appropriate torque relative to the
17   position of the cursor on the screen, in accordance with the
18   relevant torque-position profile for that screen display. The D/A
19   544 for each axis receives the digital torque information and
20   produces the appropriate analog signal to the power driver(s) 546
21   which generate a current to apply the positive or negative torque
22   to the motors resulting in the applicable tactile responsiveness of
23   the ball 504.

24   When the trackball or mouse is moved to effect a movement of
25   the cursor on the display screen 530, each encoder 536 sends
26   position information to the microprocessor 538.   Position

- 28 -

1   information in this illustrative embodiment includes an indication

2   of the direction and number of steps the encoder is changed in

3   response to actuation of the associated wheel set in contact with

4   the manually manipulated ball 504. The microprocessor 538 receives

5   the magnitude and direction information and tracks the position in

6   the spatial array of relevant torque profile information to

7   determine the appropriate torque corresponding to the position

8   information received. The microprocessor 538 communicates the

9   position information to the user interface device driver which

10   effects a change in the position of the cursor by communicating

11   with the computer as is appreciated by those of skill in the art.

12   The microprocessor 538 also conveys torque information to the servo

13   motors, via the D/As and power drivers as described, to effect

14   appropriate tactile responsiveness based on cursor position within

15   the screen display of the particular application and torque-

16   position information.

17   The torque-position information stored and made accessible to

18   the microprocessor for implementing tactile responsiveness of the

19   user interface device according to the invention can be used to

20   implement various tactile responses as a function of position of

21   the cursor on the screen display. Boundaries for cursor

22   containment and restricted display areas can be implemented by

23   effecting stops using maximized motor torque. Among other

24   responsiveness, tactile "hills" and "troughs" can be implemented to

25   define tactile contours of a graphical user interface such as

26   illustrated in Figs. 13A-13D. In this particular example of an

1   application, a graphical user interface includes a header showing

2   a command options banner as it appears on the display screen (Figs.

3   13a and 13B).

4   The command options banner is a button bar on which a cursor

5   is positioned by a user using a user interface device to point and

6   click to effect certain functionality. The various commands, i.e.

7   "File," Options," "Window," "Help" can be delineated by tactile

8   boundaries according to the invention, so that the proper

9   positioning of the cursor within an appropriate area to click and

10 invoke the command can be easily done and can be tactilely

11 perceptible. With or without fine motor skills or vision, the user

12 actuates the user interface device according to the invention and

13 feels the position of the cursor on the screen display. Tactile

14 boundaries are programmed, as discussed hereinbefore and as

15 illustrated in Figs 13C and 13D, so that higher resistance is

16 perceived at the boundaries with little or no resistance felt when

17 the cursor is properly positioned.

18   Moving the cursor vertically on the screen toward the button

19 bar the user will perceive neutral or no resistance in the

20 unrestricted area 560. A sharp increase in torque will be felt as

21 the lower boundary 562 of the button bar is encountered. When the

22 cursor is actuated to a position between the lower boundary and an

23 upper boundary, i.e. in a trough 564, no resistance is perceived.

24 As the upper boundary 566 is approached the torque increases and as

25 the absolute boundary of the screen is encountered increased torque

26 effects a perceptible stop 568. It should be noted that positive

- 30 -

1   and negative torques can be generated according to the invention so

2   that the user interface device includes a tendency to urge the

3   cursor into a position centered within the boundaries.

4   Likewise, when the user interface device is actuated to move

5   the cursor horizontally along the button bar, as illustrated in

6   Fig. 13D, boundaries are established that urge the cursor into the

7   proper position to activate the desired menu selection.

8   It should be appreciated that in addition to boundaries formed

9   by hills and troughs and walls, the tactile responsiveness of the

10   user interface device according to the invention can be used to

11   implement "texturing" that is tactilely perceptible.   Slight

12   increases in torque can be programmed at selected distances with

13   lesser torque therebetween such that a feeling of bumpiness can be

14   implemented as the cursor is actuated across a screen display.

15   Elasticity, in the form of increasing torque to a point of reverse

16   torque, can be implemented to simulate perceived stretching or

17   resiliency.   Furthermore, given the active nature of the torque

18   assistance capability of the motor(s) in the user interface device

19   according to the invention, motion assistance can be effected to

20   make the device roll off of a bump or hill without manual

21   assistance (such an application is especially useful where a user

22   may not have fine motor skills).

23   The EEPROM resident tables or arrays of torque profile

24   information will not change until a new set of profiles is

25   programmed, i.e down loaded, into the microprocessor accessible

26   memory.   Thus, when the system is powered down and subsequently

● ●

1 powered up, the previously selected torque profile is resident and

2 available as a default mode for the respective actuators, unless a

3 particular default state is desired and provided.

4   Although the invention is described hereinbefore with a

5 singular screen display, it will be appreciated by those of

6 ordinary skill in the art that the torque position information can

7 be structured in a manner such that screens can be nested, and

8 their corresponding profiles nested so that invoking a new screen

9 from a present screen invokes a corresponding new set of torque

10 position information.

11   It should be appreciated that although tables or arrays of

12 torque profile information are discussed in the illustrative

13 embodiment herein for relating cursor screen position with tactile

14 responsiveness of the user interface device, torque values may be

15 calculated "on the fly" for particular screen displays rather than

16 storing values associated with particular positions. Additionally,

17 rather than having the user interface device providing information

18 regarding position and changes thereof, torque values may be

19 associated with particular cursor locations on a particular screen

20 display such that the screen generates the position information

21 which is processed according to the invention to provide resultant

22 tactile responsiveness.

23   In the embodiment where a slave motor is connected in series,

24 the slave motor will see the same current as the motor with which

25 it is connected in series. In such a master/slave motor pair, the

26 motors should be virtually identical motors to effect smoothness of

1   rotation of the ball or tracking element. However, in order to

2   minimize cost of a system according to the invention, it will be

3   appreciated that it may be preferable to exclude the slave motor in

4   favor of a passive bearing.

5   The description of the invention hereinbefore relates to a

6   trackball, but it will be appreciated that tactile responsiveness

7   according to the invention can be implemented in various other user

8   interface devices, including a mouse, joysticks and other devices

9   requiring actuation and benefitting from the tactile responsiveness

10 as a function of position. Further, while "a cursor" is

11 manipulated in the embodiment described herein, that term is used

12 generically to describe something manipulated in a user interface

13 of an electronic device, and it should be appreciated that any of

14 various symbols and interface or display resident entities can be

15 manipulated with tactile responsiveness, such as cursors, icons,

16 windows, menus, or the like.

17   While various embodiments of the invention illustrated herein

18 describe a main CPU to execute an application program requiring and

19 defining torque profiles for an actuator, and a separate 6809

20 microprocessor implementing firmware specifying torque-position

21 relationships, one of ordinary skill in the art will appreciate

22 that torque-position relationships can be implemented in the

23 application CPU without the microprocessor or via numerous other

24 microcontrollers. Further, while it is described that the torque

25 profiles are in EEPROM accessible to the microprocessor it will be

26 appreciated that the torque profiles can be stored in

1 microprocessor resident or other storage means, such as ROM, RAM,

2 PALs and the like, and accessed accordingly to implement the

3 desired tactile responsiveness in an actuator.

4 Although the invention has been shown and described with

5 respect to exemplary embodiments thereof, various other changes,

6 additions and omissions in the form and detail thereof may be made

7 therein without departing from the spirit and scope of the

8 invention.

- 34 -

CLAIMS

What is claimed is:

1   1.   A user interface device to manipulate a position of a cursor

2   on a screen display in an electronic apparatus, comprising:

3   a tracking element actuatable to track the position of said

4   cursor on said screen display;

5   at least one motor interconnected to said tracking element and

6   having a position encoder connected thereto, each said position

7   encoder generating a motor position signal indicative of the

8   position of a respective motor;

9   a controller receiving cursor position information from said

10 electronic apparatus and motor position information from a

11 respective encoder;

12   a store of force-position information accessible to said

13 controller, said controller accessing said store of force-position

14 information in response to at least one of said cursor position

15 information and said motor position signal to generate, using said

16 at least one motor, a positive or negative force in said tracking

17 element as a function of a position of said cursor on said screen

18 display.

19 2.   The user interface device of claim 1 wherein said tracking

20 element is a sphere interfaced to said at least one motor by at

21 least two sets of wheels contacting said sphere and said at least

22 two sets of wheels are aligned on mutually orthogonal axes.

23 3.   The user interface device of claim 2 wherein each of said at

24 least two sets of wheels comprises a hub about which a pair of

25 frames is disposed and each of said pair of frames includes

26 gripping members staggered in a manner so that there is always a

27 gripping member in contact with said sphere.

28 4.   The user interface device of claim 1 wherein said at least one

29 motor comprises a plurality of motors and each of said plurality of

30 motors has an associated complementary motor connected in series.

31 5.   The user interface device of claim 1 wherein said at least one

32 motor comprises a plurality of motors and each of said plurality of

33 motors has an associated complementary bearing.

34 6.   The user interface device of claim 1 wherein said at least one

35 motor comprises a plurality of motors each interconnected to said

36 tracking element by at least one set of wheels aligned on mutually

37 orthogonal axes and configured to sense or impart motion of the

38 tracking element on a respective axis.

39 7.   The user interface device of claim 6 wherein said plurality of

40 motors each interconnected to said tracking element by at least one

41 set of wheels aligned on mutually orthogonal axes are configured to

42 sense or impart motion of the tracking element on mutually

43 orthogonally disposed x and y-axes.

- 36 -

44   8.   The user interface device of claim 7 further including at

45   least one set of wheels configured to sense or impart motion of the

46   tracking element on a z-axis orthogonally disposed with respect to

47   said x and y-axes.

48   9.   A method of generating tactile responsiveness in a user

49   interface device having a tracking element manipulating a position

50   of a displayed element on a display screen of an electronic device,

51   said method comprising the steps of:

52   positioning a plurality of drive/position assemblies along

53   mutually orthogonal axes with respect to said tracking element,

54   each of said plurality of drive/position assemblies including a

55   motor and an associated encoder to drive and sense position of said

56   tracking element;

57   interfacing said user interface device to said display screen

58   via a controller that receives information from said associated

59   encoder of each of said plurality of drive/position assemblies and

60   from said electronic device to track movement of said tracking

61   element and the position on said display screen of said displayed

62   element;

63   storing force-position relation information, accessible to

64   said controller, as a function of the position on the display

65   screen of the displayed element; and

66   accessing said force-position information via said controller

67   and generating a signal to each of said plurality of drive/position

68   assemblies to effect a positive or negative force to respectively

69   assist or resist motion of said tracking element depending upon the
70   position of said displayed element on said display screen.

71   10. The method of claim 9 wherein said step of positioning a
72   plurality of drive/position assemblies further includes positioning
73   a corresponding plurality of complementary slave assemblies along
74   corresponding mutually orthogonal axes, each of said complementary
75   slave assemblies being electrically connected in series with a
76   respective one of said plurality of drive/position assemblies.

77   11. The method of claim 9 wherein the step of interfacing said
78   user interface device to said display screen via said controller
79   includes interconnecting said electronic device to said controller
80   to send and receive information about the position of the displayed
81   element on said display screen between said electronic device and
82   said   controller,   and   interconnecting   said   plurality   of
83   drive/position assemblies to said controller to send said signal to
84   each of said plurality of drive/position assemblies to effect said
85   positive or negative force to respectively assist or resist motion
86   of said tracking element depending upon the position of said
87   displayed element on said display screen.

88   12. A user interface device having tactile feedback capabilities,
89   comprising:
90   an actuatable member for imparting a tactile feedback to a
91   user of said user interface device;

92   a motor interconnected to said actuatable member;

93   a position encoder in communication with said motor, said

94 position encoder providing position information of said motor;

95   a controller receiving said position information from at least

96 said position encoder;

97   a store of force-position relation information accessible to

98 said controller, said controller outputting at least one force

99 value corresponding to said position information in accordance with

100 said store of force-position relation information; and

101   a drive signal source generating a drive signal to said motor

102 in accordance with said at least one force value, said drive signal

103 causing a force in said motor to provide said tactile feedback to

104 said actuatable member to assist or resist motion of said

105 actuatable member.

106   13. The user interface device of claim 12 further including a

107 counter receiving said position information of said motor and

108 providing a count to said controller, said controller outputting a

109 force value corresponding to said position information in

110 accordance with said store of force-position relation information.

111   14. The user interface device of claim 13 wherein said force value

112 is a digital force value and further including a digital to analog

113 converter receiving said digital force value and converting said

114 digital force value to an analog force signal.

115 15. The user interface device of claim 14 further including a
116 power amplifier receiving said analog force signal and generating
117 said drive signal to said motor in accordance with said at least
118 one force value, said drive signal being proportional to said
119 analog force signal.

120 16. The actuator of claim 12 wherein said controller is a
121 microprocessor receiving said position information on at least one
122 port thereof.

123 17. The actuator of claim 16 wherein said microprocessor includes
124 resident erasable programmable read only memory which is used for
125 said store of force-position relation information.

126 18. The actuator of claim 12 wherein said drive signal source is
127 a current source including a power amplifier and said drive signal
128 is a current provided by said power amplifier.

1/15
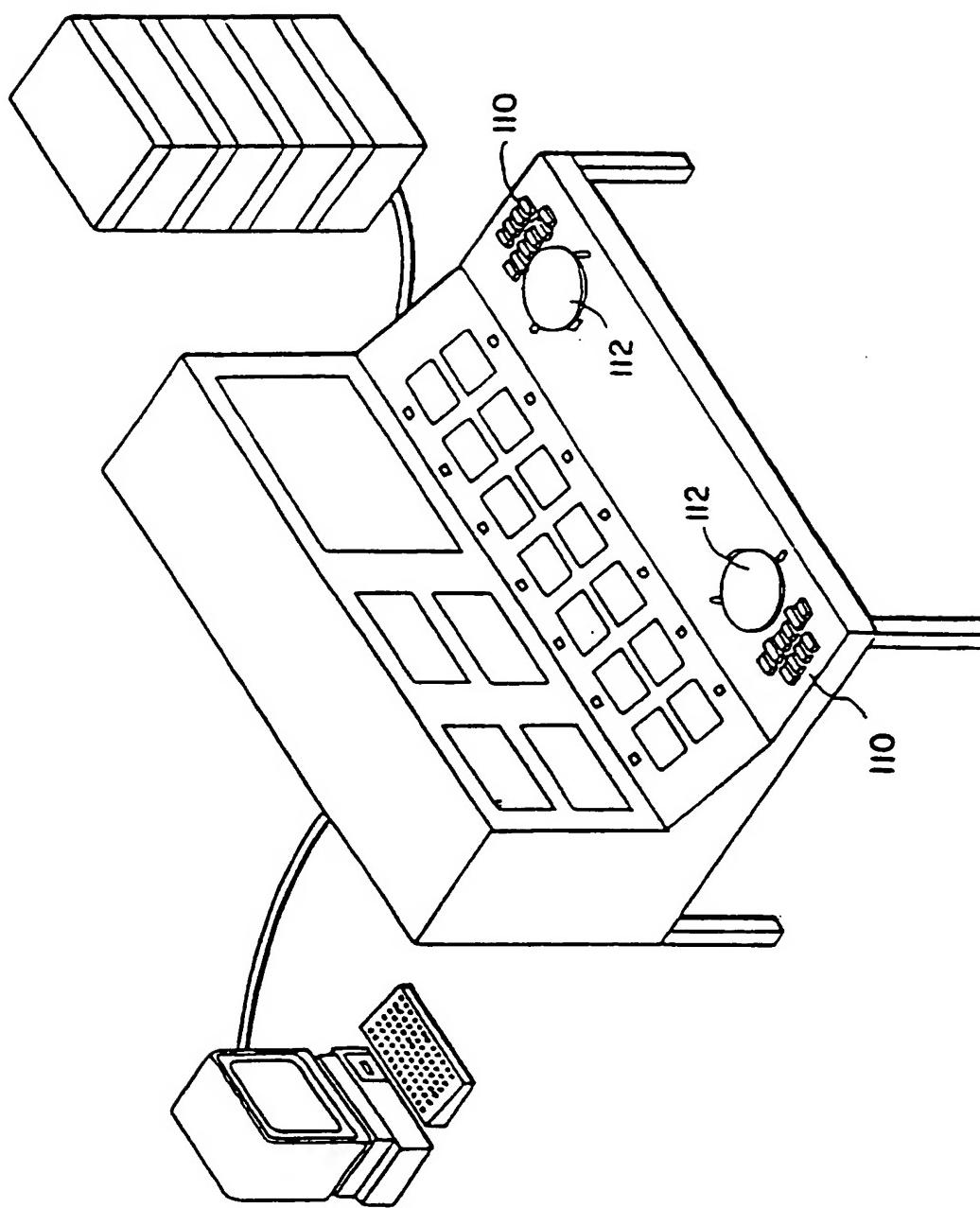
FIG. 1
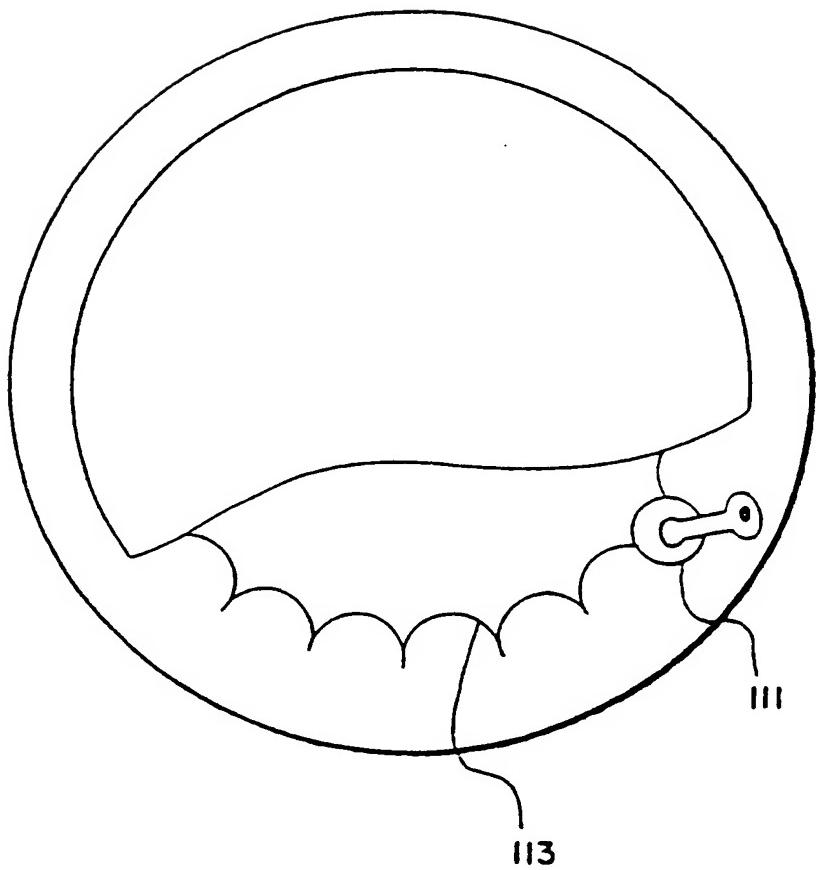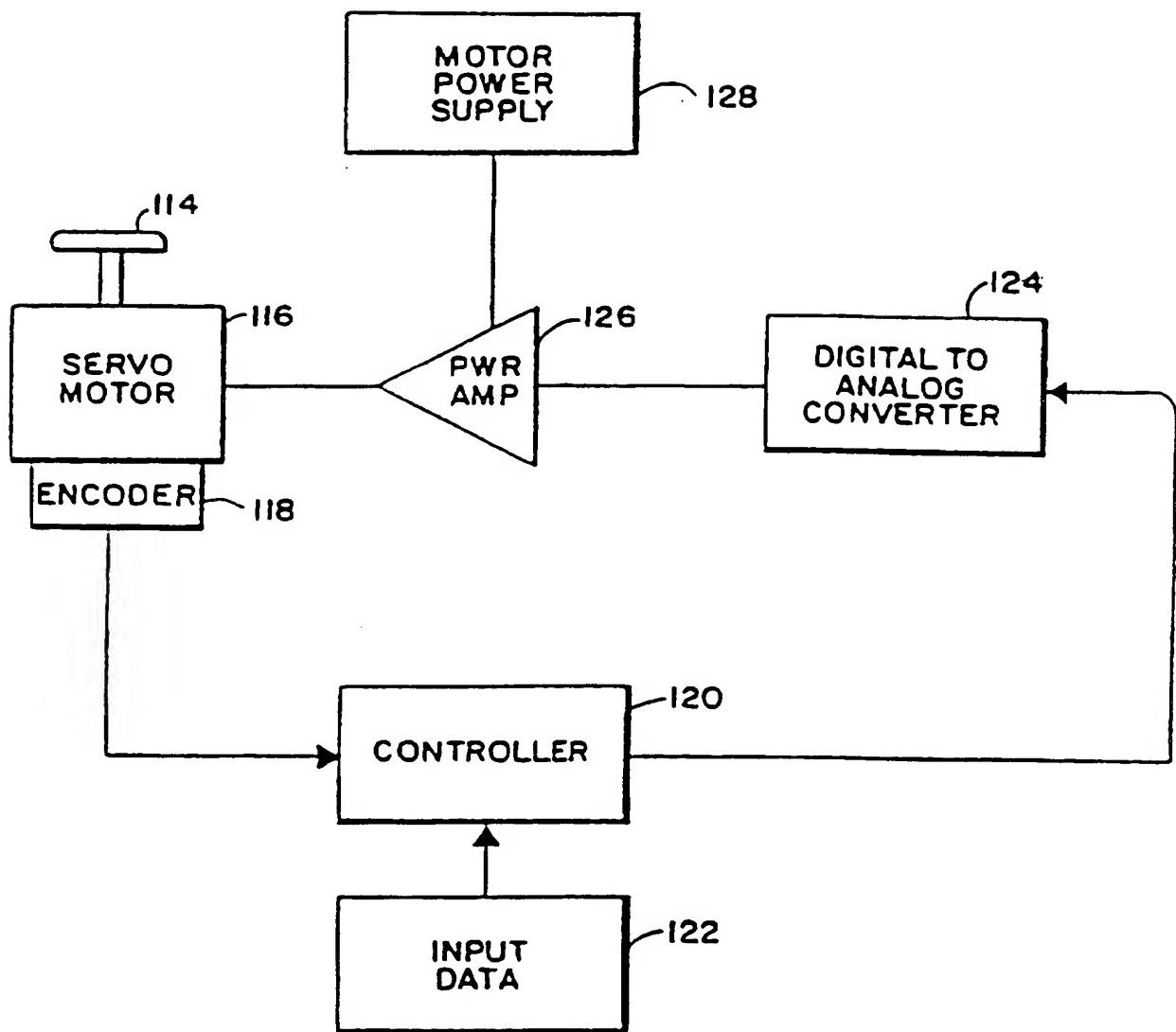
111

113

FIG. 1a
(PRIOR ART)

FIG. 2

4/15

```
        ┌──────────────┐
        │    MOTOR     │
        │    POWER     │──── 128
        │   SUPPLY     │
        └──────┬───────┘
               │
  ┌──────114   │
  ┌─┴─┐        │
  │   │        │
  ┌───┴───┐    │    ╱│              ┌──────────────┐ ── 124
  │       │─116│   ╱ │ ── 126       │  DIGITAL TO  │
  │ SERVO │    └──╱  │──────────────│   ANALOG     │◄────┐
  │ MOTOR │       ╲PWR│             │  CONVERTER   │     │
  │       │────────╲AMP│            └──────────────┘     │
  └───┬───┘         ╲│                                   │
  │ENCODER│                                              │
  └───┬───┘                                              │
  118 │                                                  │
      │    ┌─ 130                                         │
      │    ╷ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─  │
      │    │  ┌─────────┐   ┌──────────────┐ ── 132   │  │
      │    │  │         │   │    MICRO     │──────────┼──┘
      └────┼─►│ COUNTER │──►│  PROCESSOR   │          │
           │  │         │   │              │          │
           │  └─────────┘   ├──────────────┤          │
           │          ┌─────│  FIRMWARE    │◄────┐    │
           │       134│     │   TORQUE/    │     │    │
           │          └─────│ POSITION TBL │  RS-232 PORT
           │                └──────────────┘     │    │
           │                                      │    │
           │                ┌──────────────┐      │    │
           │                │     MAIN     │◄─────┘    │
           │                │ APPLICATION  │           │
           │                │     CPU      │── 136  ── 120
           │                └──────────────┘      │
           │ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─
```

FIG. 3

FIG. 3a

FIG. 4

7/15

312

TORQUE
ADJUST
PROFILES

310

TORQUE
CONTROLLER

304

308

302

Fig.-5B

300

306

304

L

PRIOR ART

Fig. 5A

Fig. 6

504

500

501

505
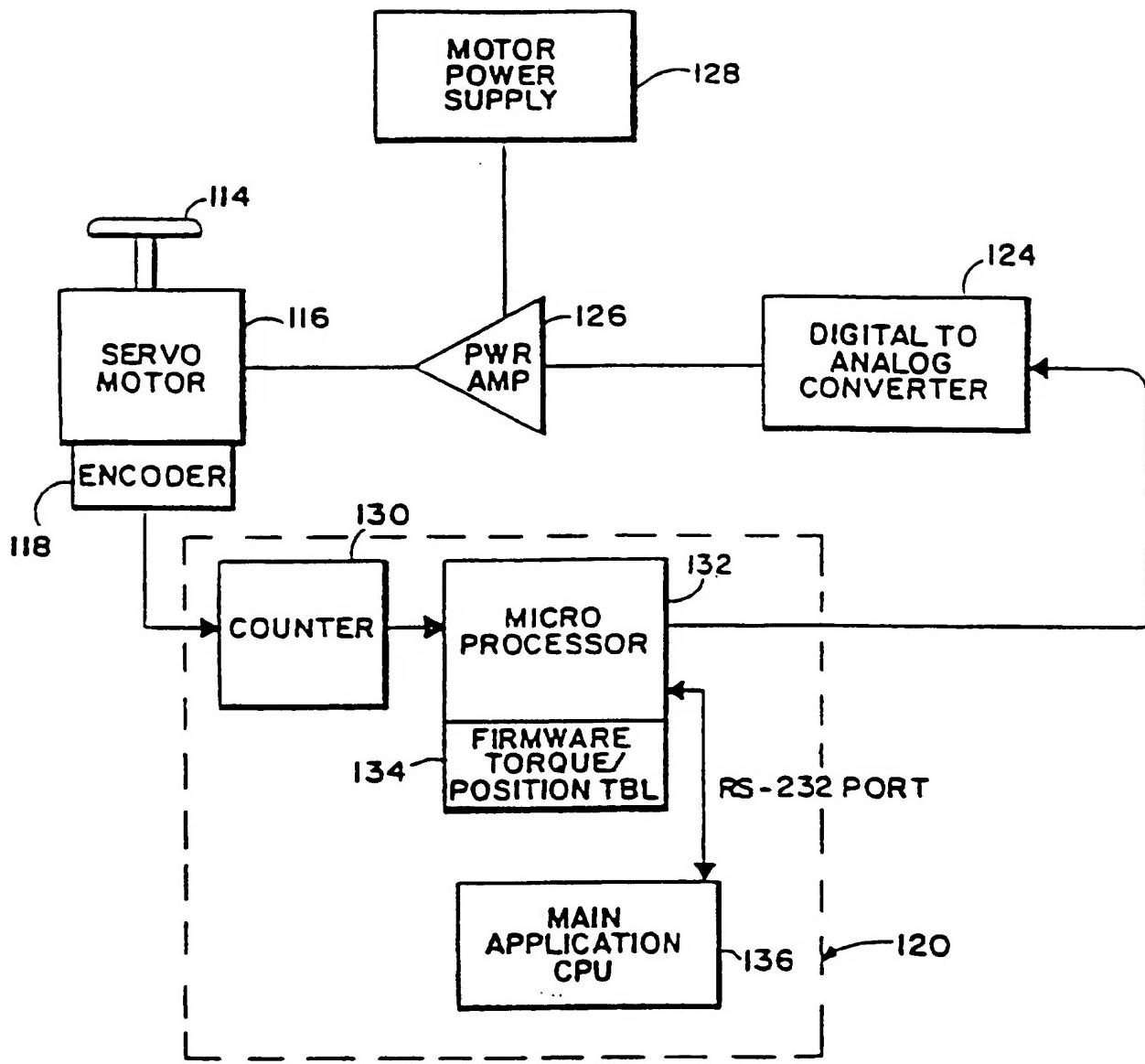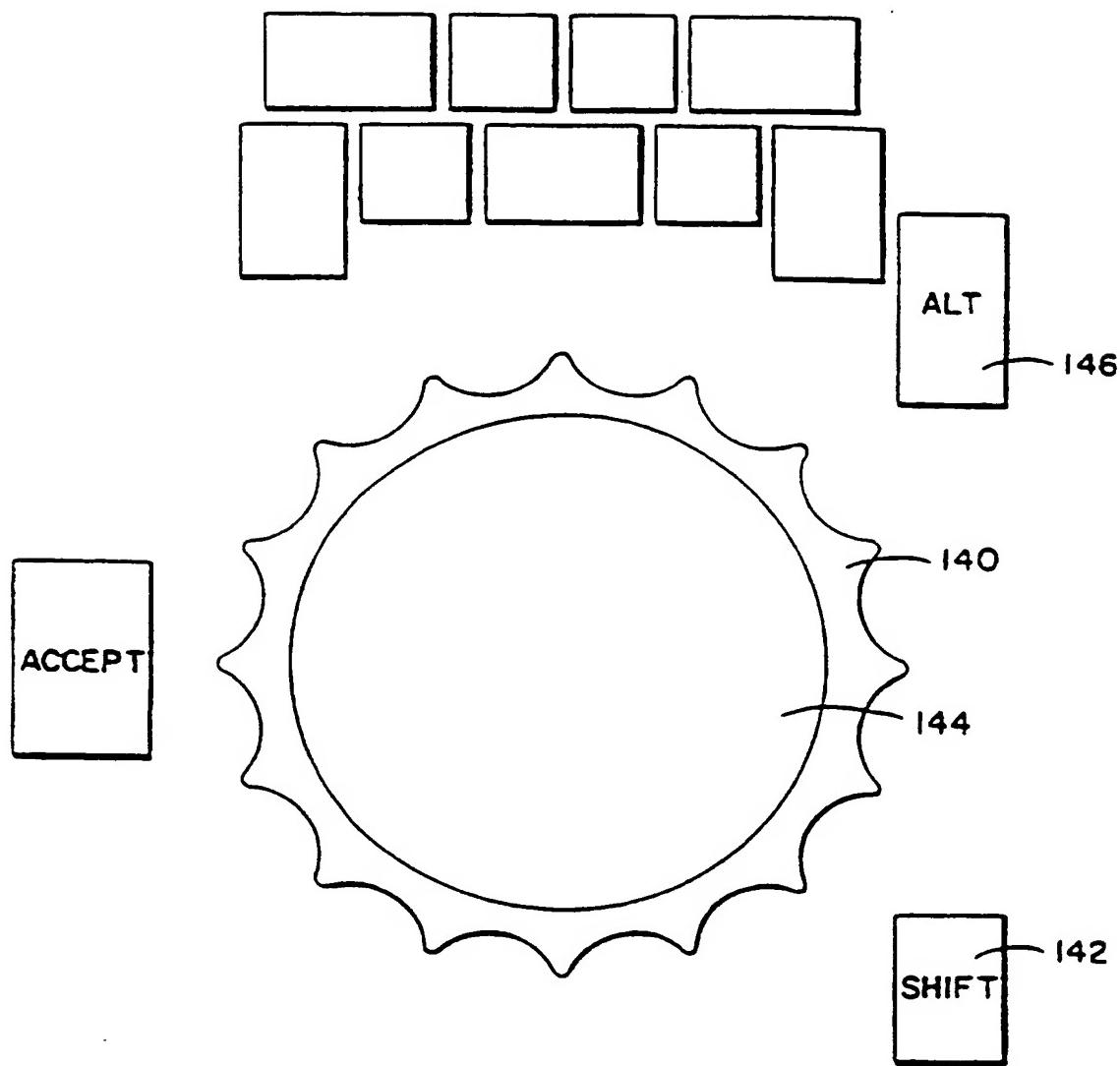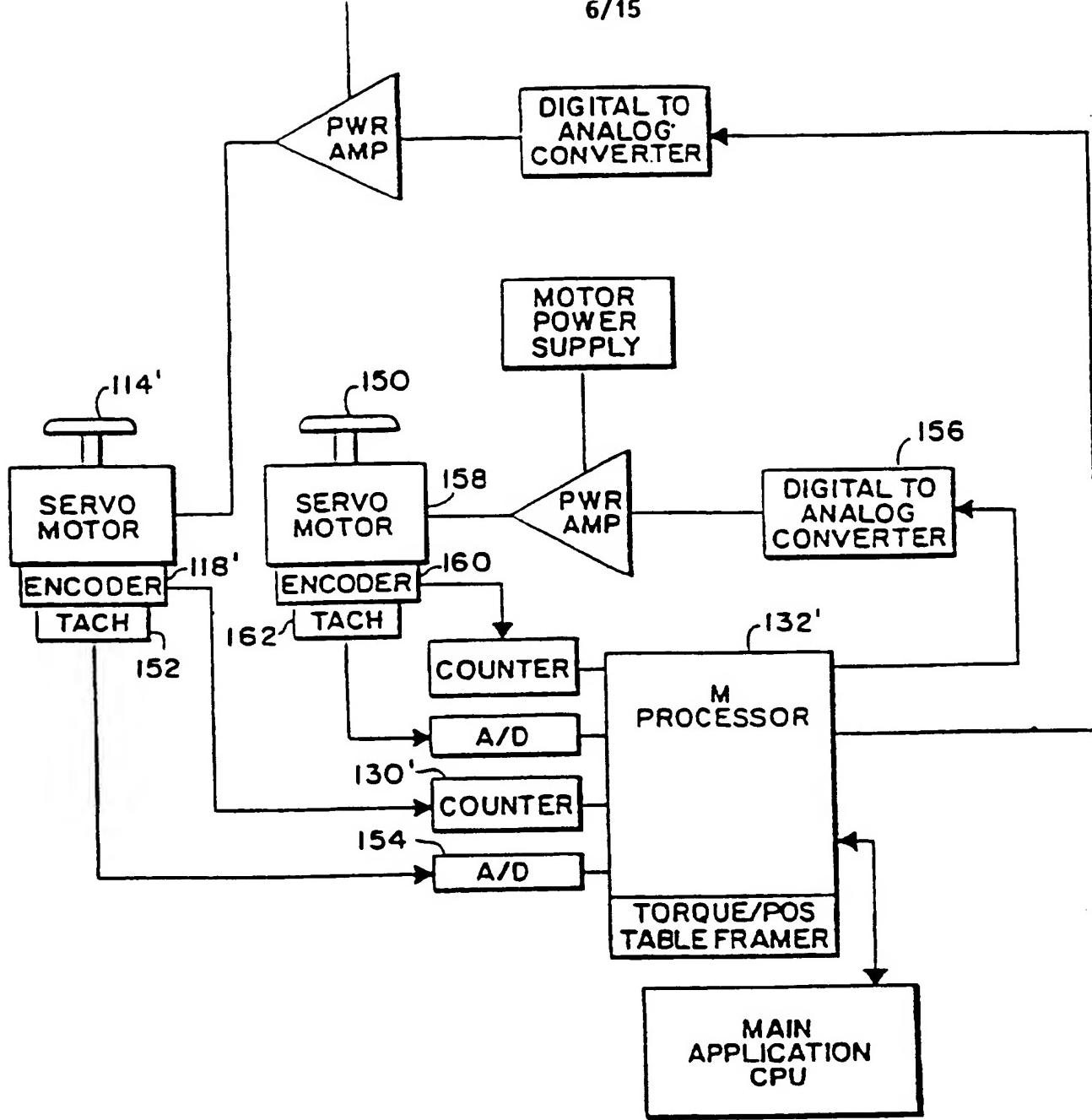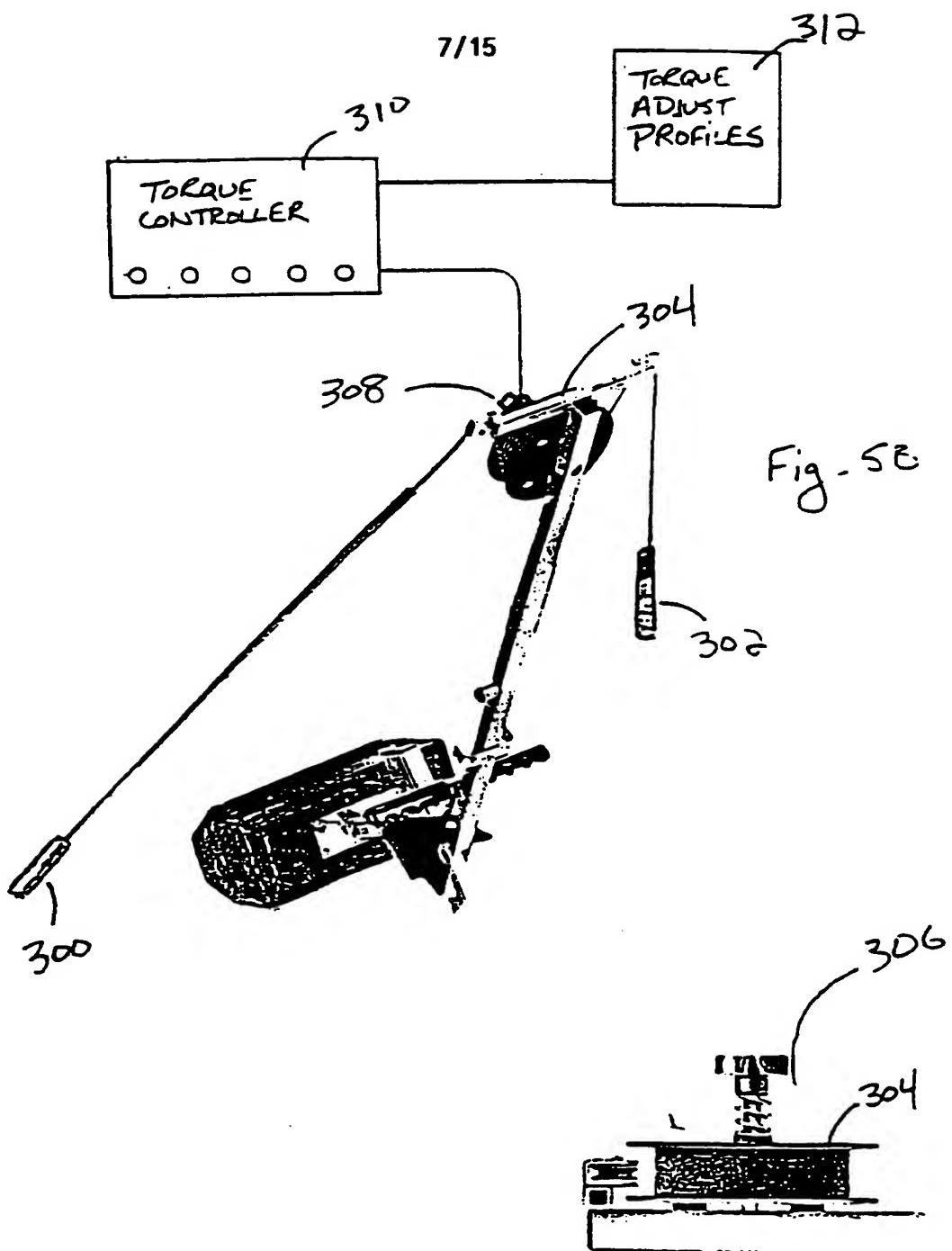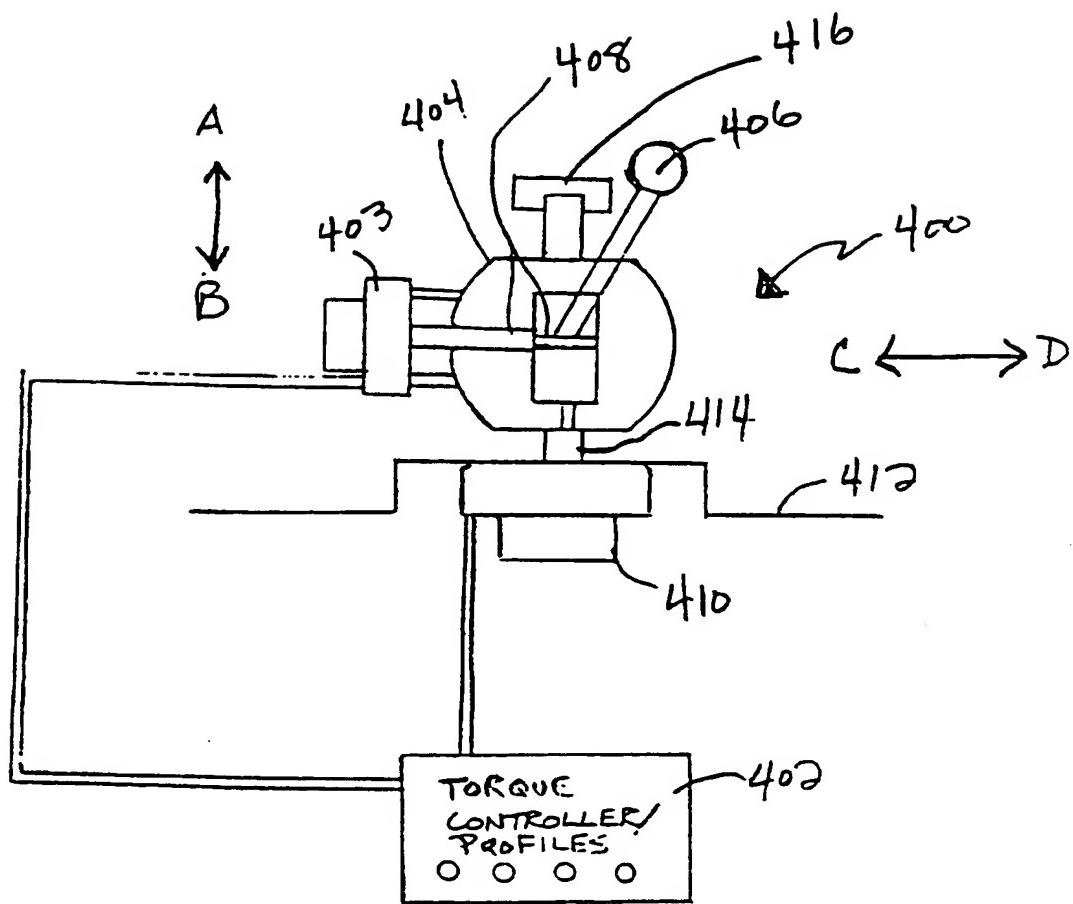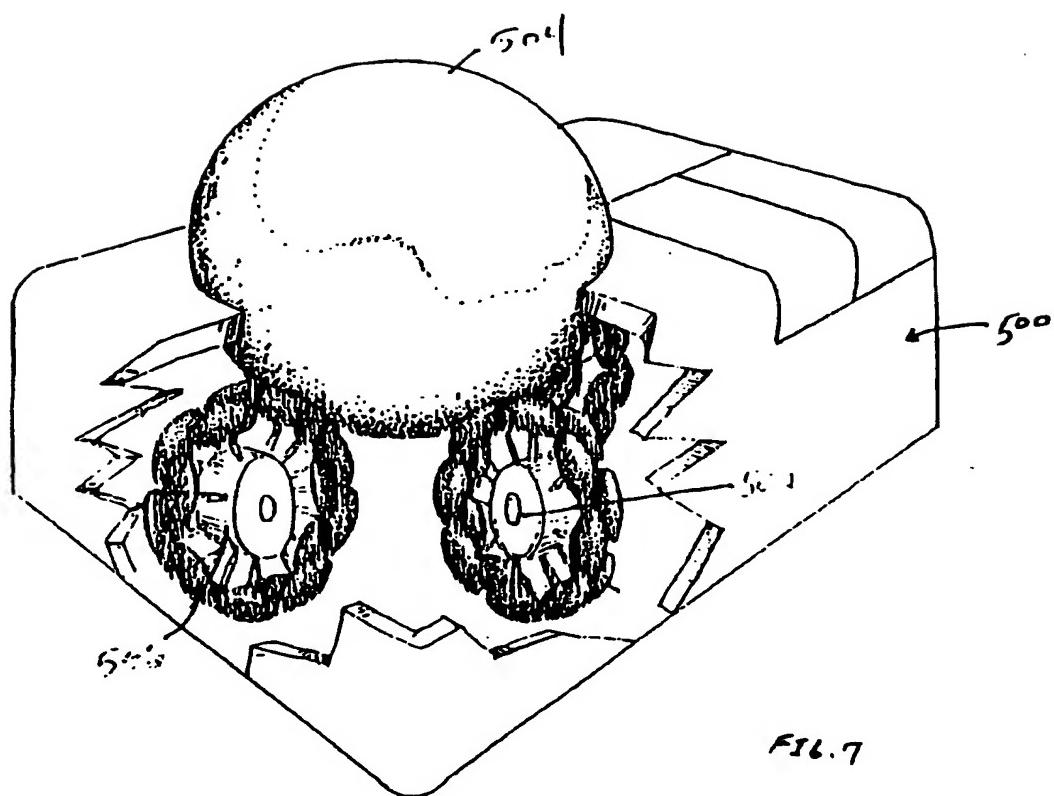
FIG.7
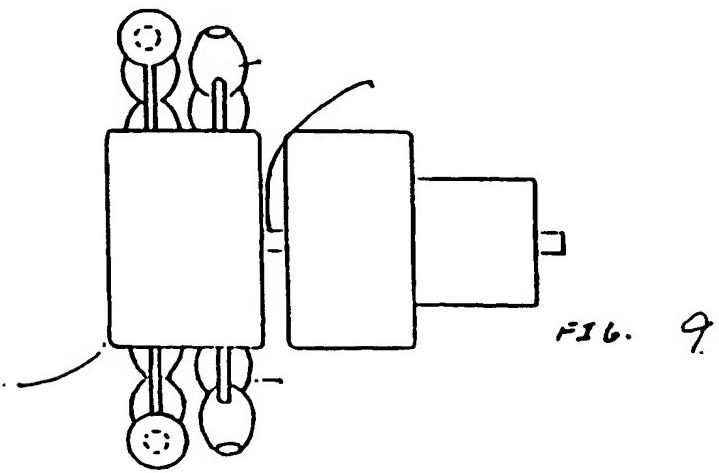
FIG. 9

Montage Electronic   ckball Patent Application   11/16/94
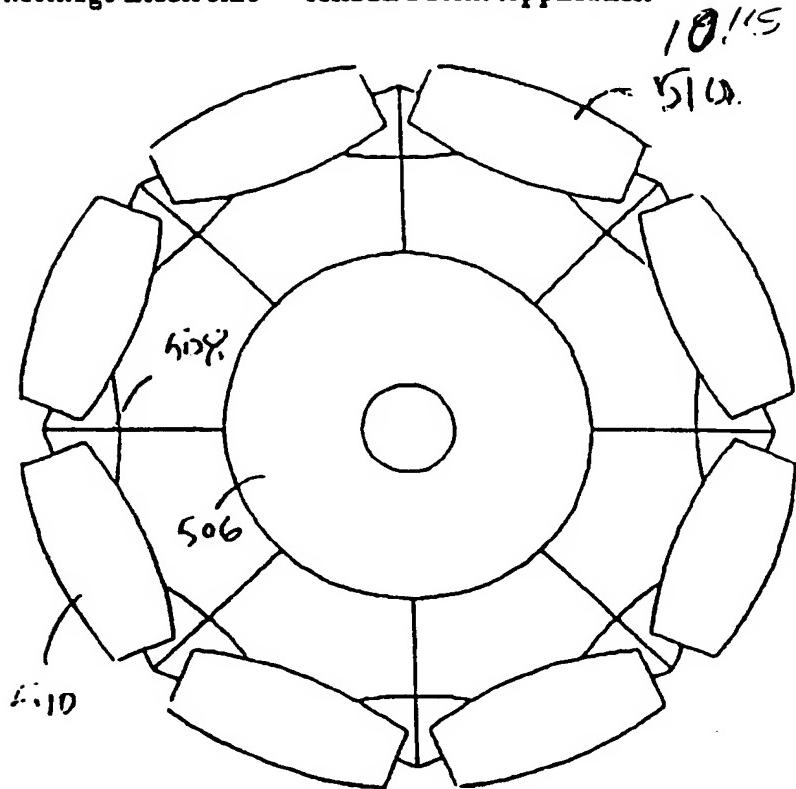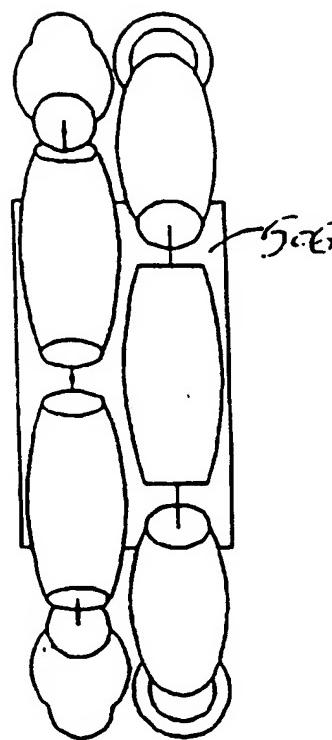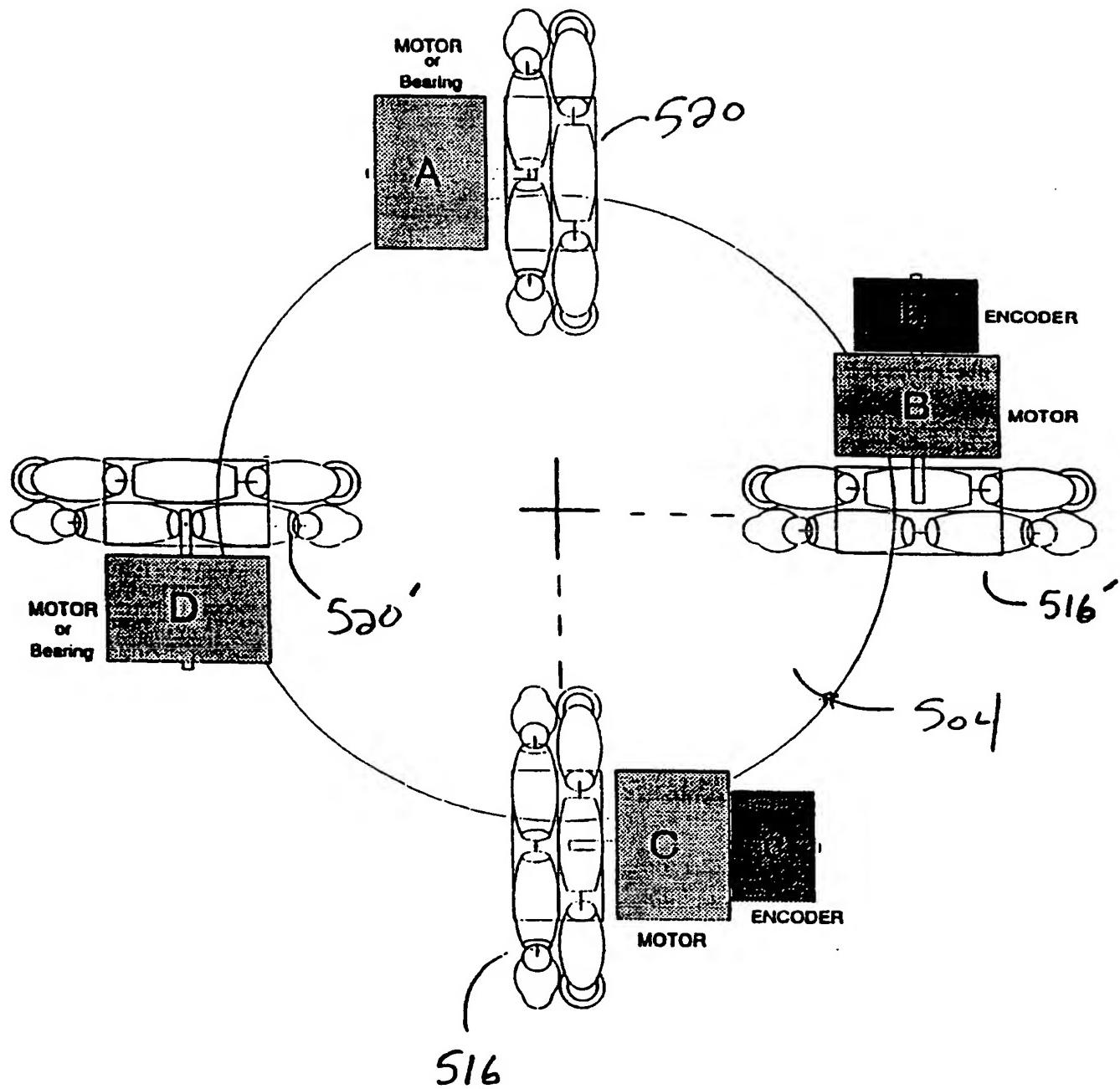
Fig. 8B

Fig. 8A

MOTOR
or
Bearing

A

520

ENCODER

B

MOTOR

516'

504

MOTOR
or
Bearing

D

520'

C

MOTOR

ENCODER

516

BOTTOM VIEW

FIG.

10 A

FIG. 11

USER INTERFACE
DEVICE DRIVER — 554

TORQUE PROFILE
INFORMATION — 552

Application/
Operating System — 550
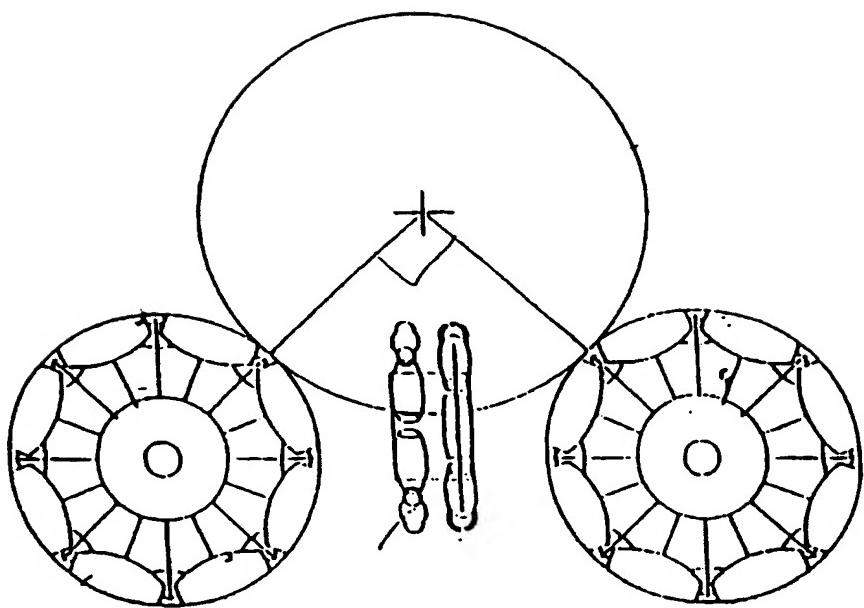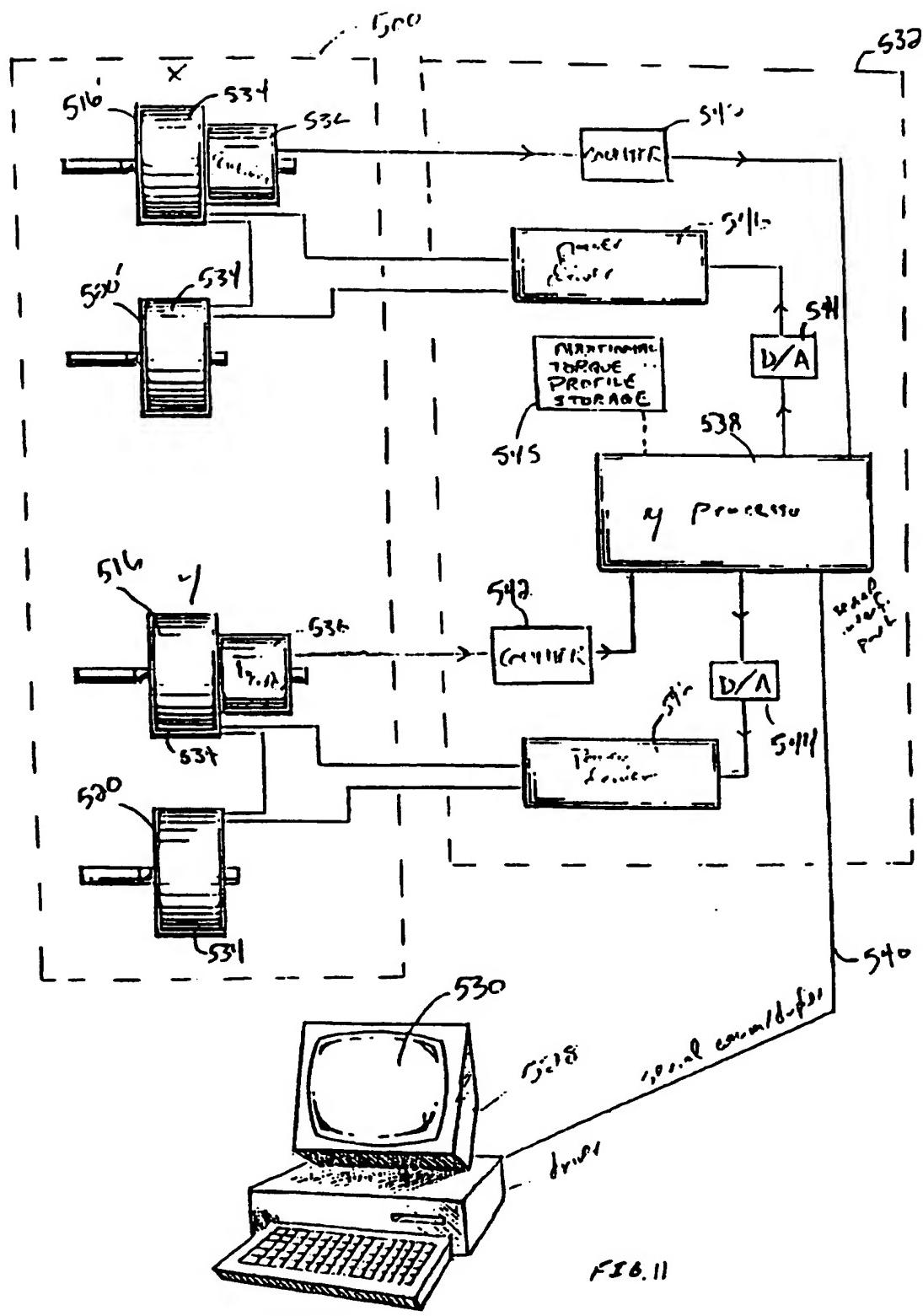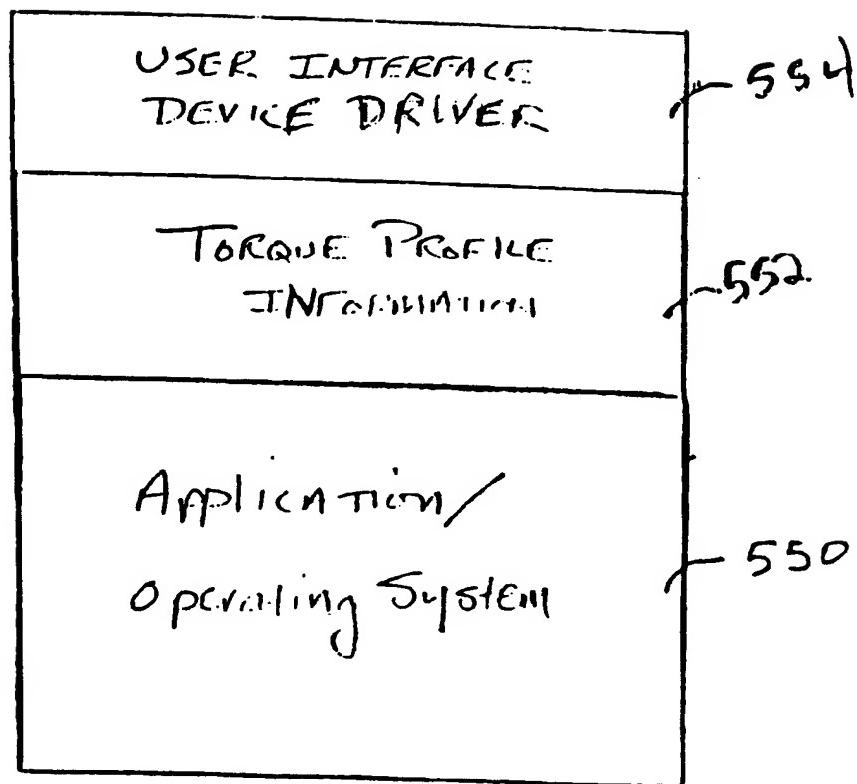
Fig. 12

Here is a windows h‧‧ ‧r showing the command options banner ‧ appears on the screen.


Fig. 13A

560
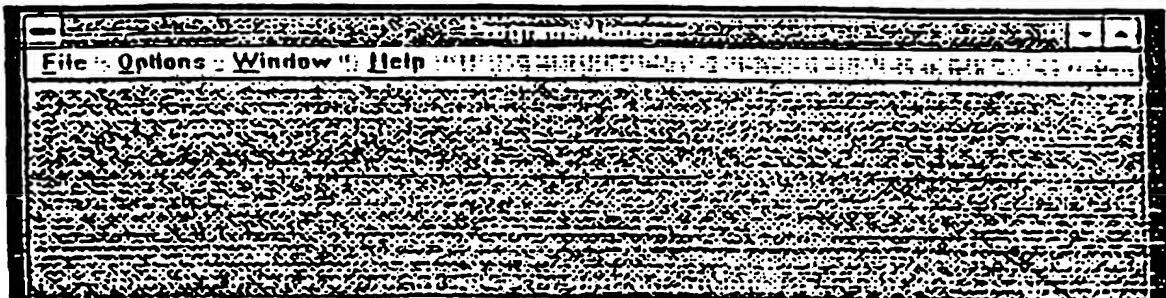
Dark lines have been added to define a torque trough arrows indicate motion in X & Y axes.

562
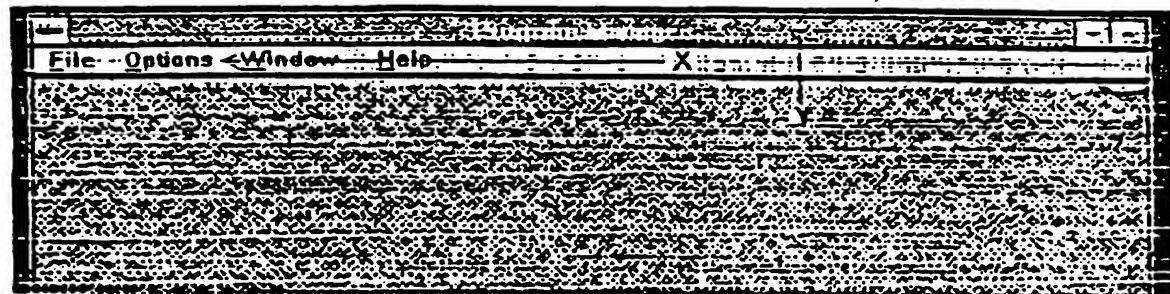
Fig. 13B

Curves below show torque profile for X & Y axes movements indicated above.
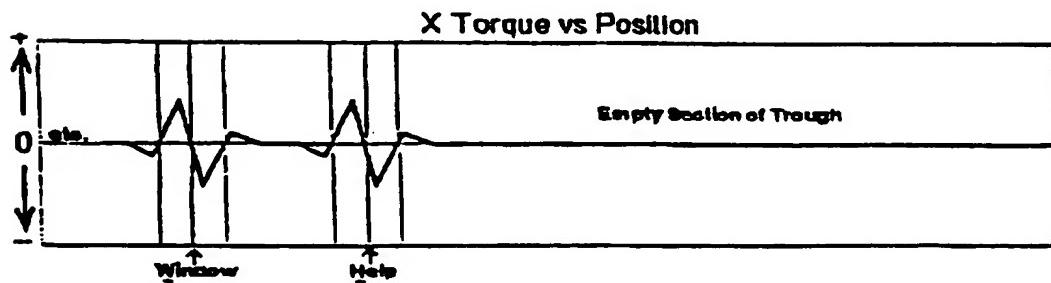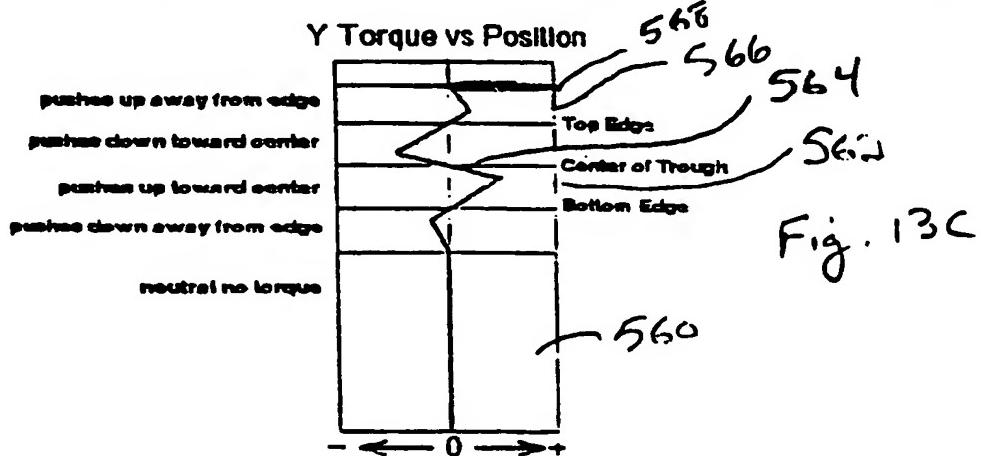
Y Torque vs Position

568
566
564
562

pushes up away from edge
pushes down toward center — Top Edge
pushes up toward center — Center of Trough
pushes down away from edge — Bottom Edge

neutral no torque

Fig. 13C

560

$-$ ⟵ 0 ⟶ $+$

X Torque vs Position

Empty Section of Trough

0 etc.

Window   Help

Fig. 13D

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G05B 13/00

US CL. : 364/188; 318/561,601,652

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 364/188-190; 318/560,561,637-638,569,600-601,615-616,646,652,687; 360/13,14.1,14.2,14.3,72.2,33.1; 340/726,723,792;

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US, A, 5,491,477 (CLARK ET AL.) 13 February 1996, col. 4. lines 44-63 and fig. 3.	1-18
A, E	US, A 5,559,412 (SCHULER) 24 September 1996, col. 2, line 40 - col. 3, line 11.	1-18
Y	US, A 5,220,260 (SCHULER) 15 June 1993, col 2, lines 30-61.	1-18
A	US, A, 4,939,594 (MOXON ET AL.) 03 July 1990, col. 2, lines 5-69.	1-18
A	US, A, 4,979,050 (WESTLAND ET AL.) 18 December 1990, col. 2, lines 15-69.	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 MARCH 1997	**1 4 APR 1997**
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer *(signature)* Reba Elmore
Facsimile No. (703) 305-3230	Telephone No. (703) 305-3800

Form PCT/ISA/210 (second sheet)(July 1992)*